D0 Results on Three-jet Production, Multijet Cross-Section Ratios, and Minimum Bias Angular Correlations

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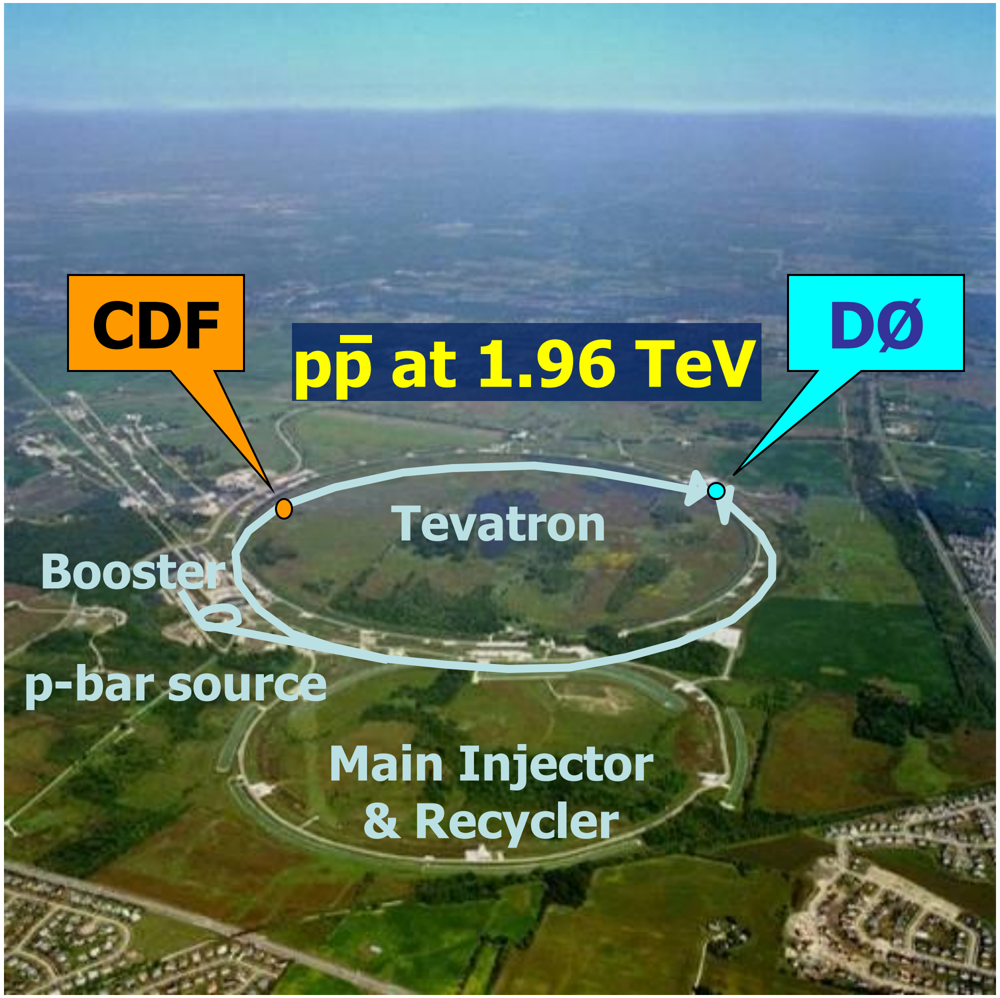
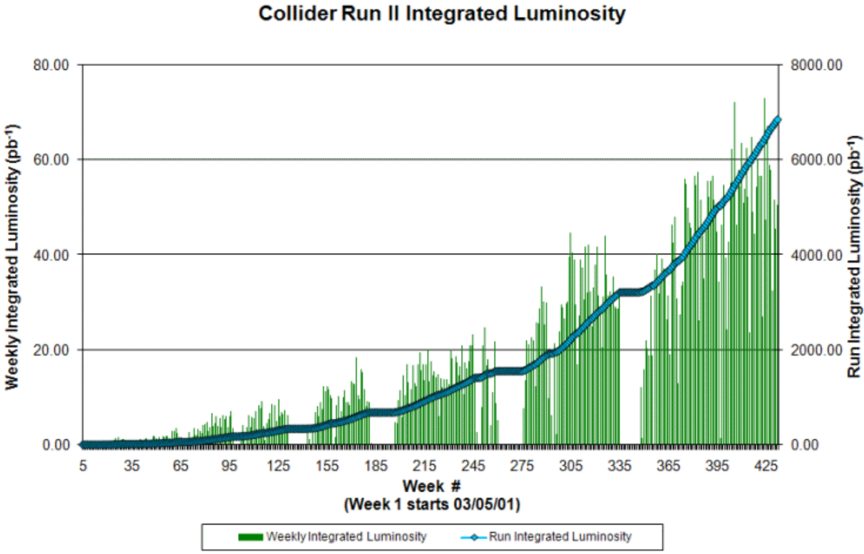
Fermilab Tevatron - Run II



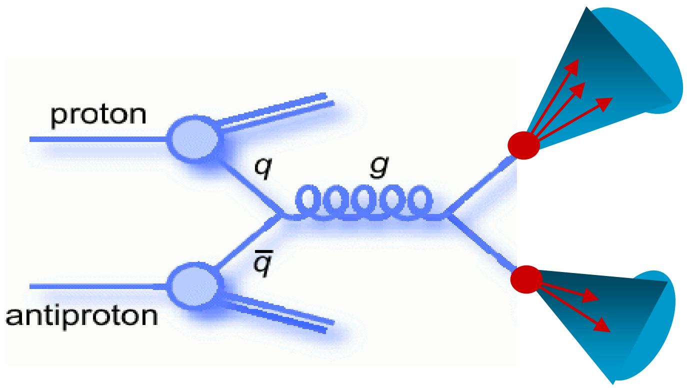
- 36x36 bunches
- bunch crossing 396 ns
- Run II started in March 2001
- Peak Luminosity:3.75E32 cm^{-2} sec^{-1}
- Run II delivered: ~7 fb^{-1}



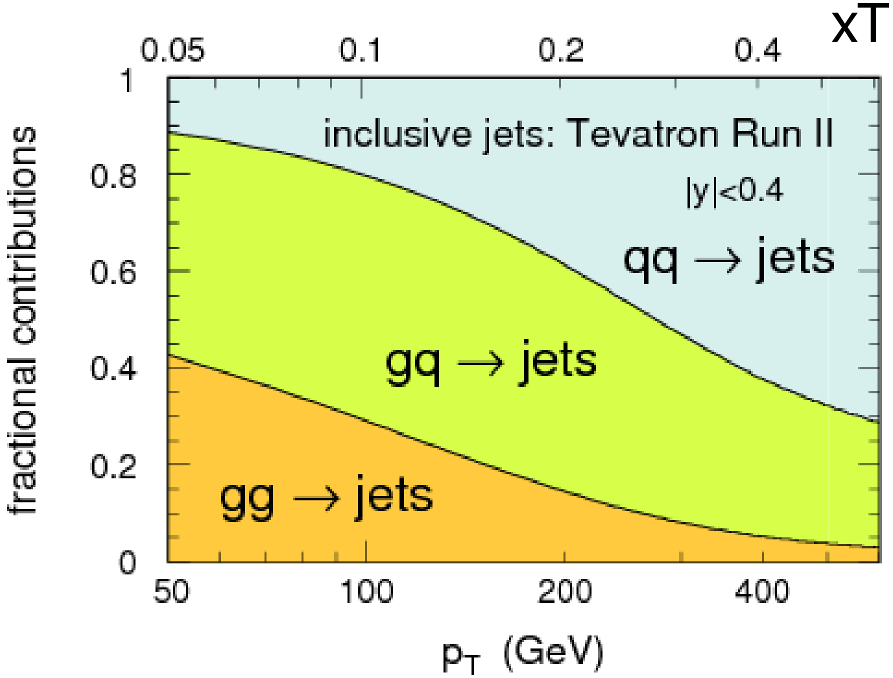
- Run II Goal: 12 fb^{-1} end of 2011

Jet Production

largest high pT cross section at a hadron collider
→ **highest energy reach**



Unique sensitivity to **new physics**:
- new particles decaying to jets,
- quark compositeness,
- extra dimensions,
- ...(?)...



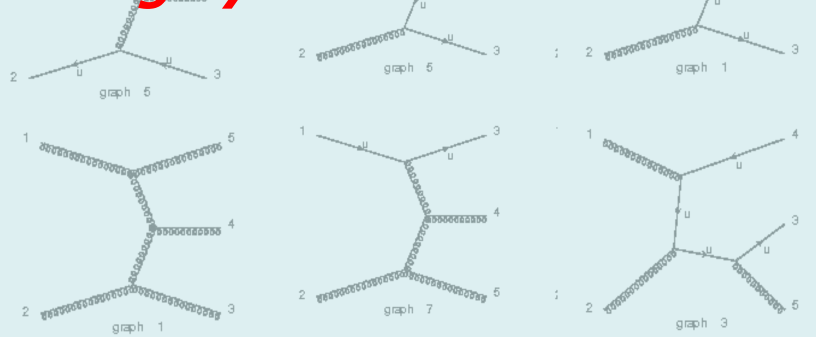
In the absence of new physics:

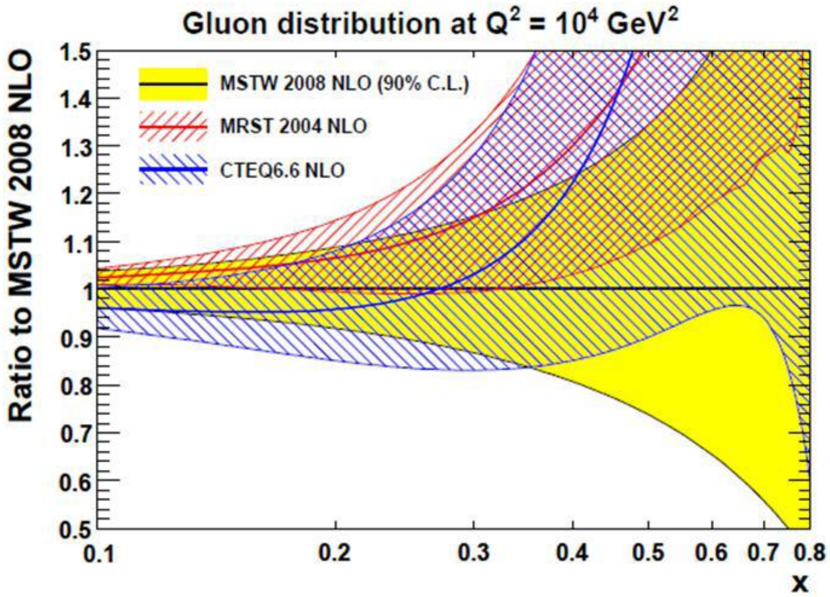
theory @NLO is reliable (±10%)

→ **Precision phenomenology**
- sensitivity to PDFs → high-x gluon
- sensitive to α_s

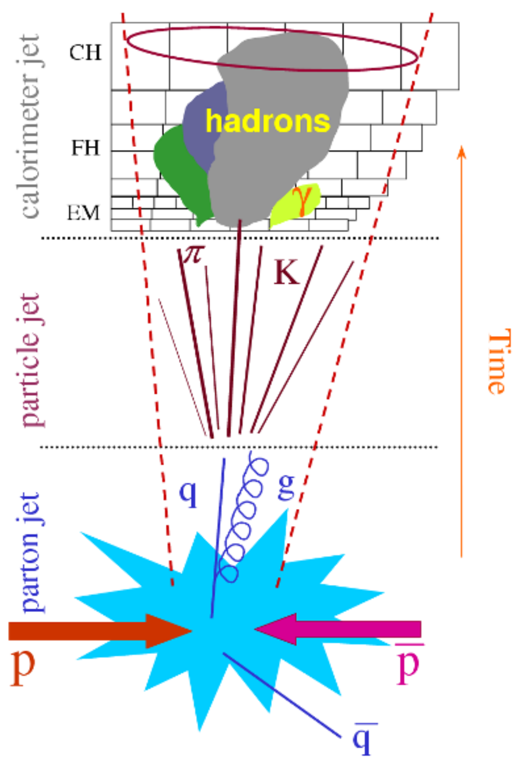
Multi-Jet Production

- ***Inclusive jet production and dijets sensitive to PDFs and α_s^2***
- ***Three-jet production***
  - ***same PDF sensitivity***
  - ***But sensitive to α_s^3***
  - ***Sensitivity to contribution from higher order diagrams.***
- ***Testing higher-order processes provides direct insight into strong dynamics***



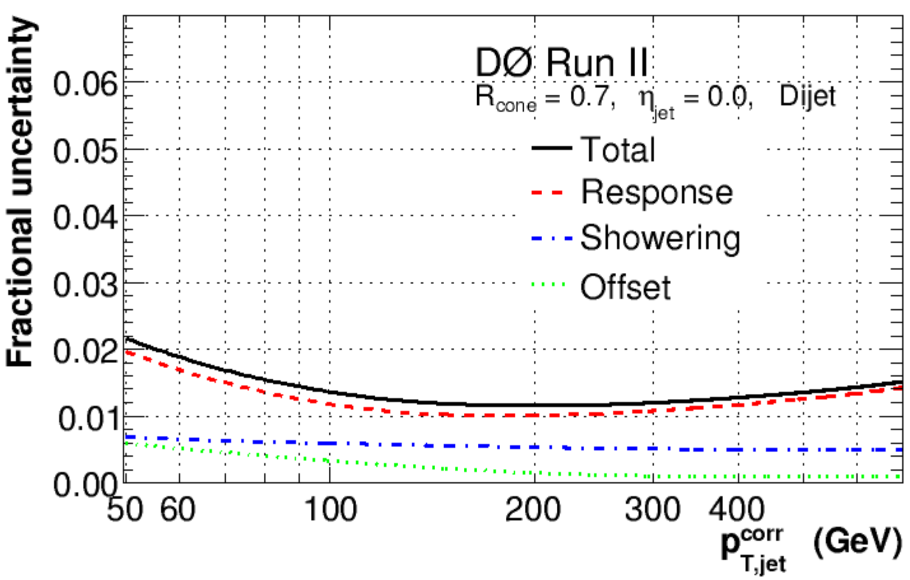


Comparing Data to Predictions



- Use Jet Definition to relate Observables defined on Partons, Particles, Detector
- Measure cross section for pp-bar → jets on "particle-level"
  - Correct for experimental effects (efficiencies, resolution, …) calculated using a fast detector parametrization
  - Include uncertainties and correlations from jet energy scale, non-pertubative effects & UE, id efficiencies, correction for muons & ν's, etc
  - Apply correction to the pQCD calculation
- Comparison to NLO pQCD implemented using NLOjet++, FastNLO program
  - Interpolation techniques for PDFs(x,μ), $\alpha_s(\mu)$

Energy scale uncertainty: 1-2% !



Three-jet Mass

First Measurement of three-jet cross section at the Tevatron

→ First corrected 3-jet mass distribution

→ First comparison to NLO pQCD calculations for 3-jet cross sections

Strategy:

Measure cross sect. vs. invariant three-jet mass

- in different rapidity intervals $|y| < 0.8, 1.6, 2.4$

For the largest rapidity interval

- for different p_T requirements of the 3rd jet $p_T^{Jet3} > 40, 70, 100$ GeV

Data Set:

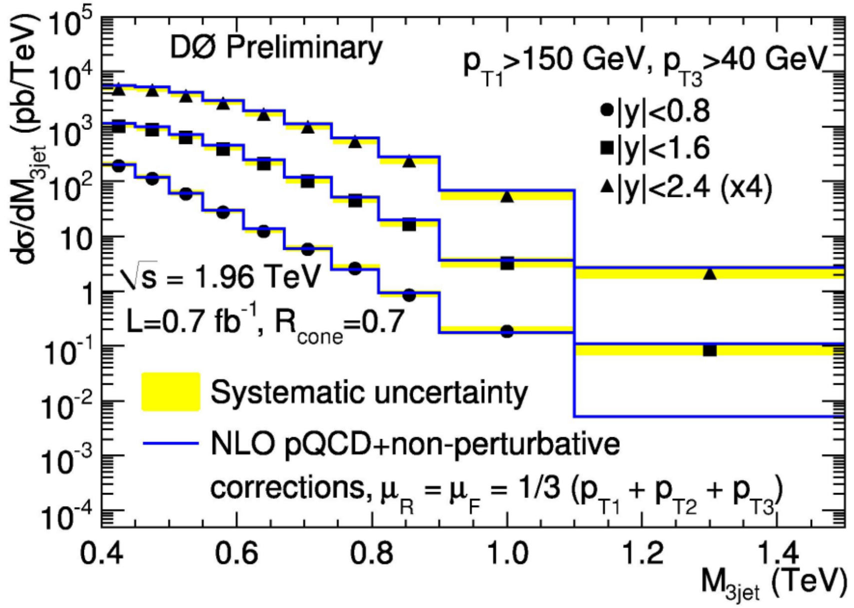
- 0.7 fb-1 inclusive jet triggers
- Require at least 3 reconstructed jets passing data quality and jet id criteria
  - Jet 1 $p_T > 150$ GeV
  - Jet 2, 3 $p_T > 40$ GeV
  - All jets separated by $\Delta R > 1.4 = 2 * R_{cone}$

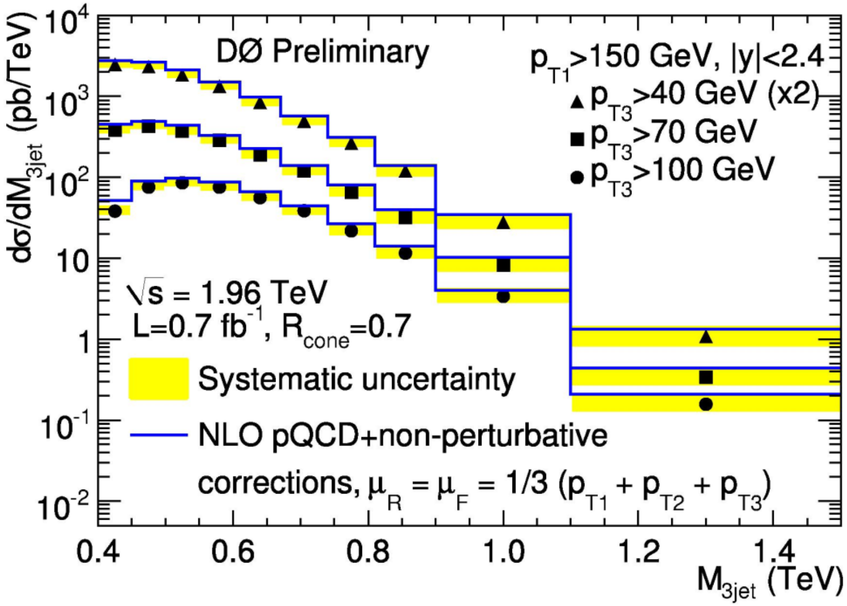
Three-jet Mass

$$\frac{d\sigma}{dM_{3jet}} = \frac{1}{L \cdot \Delta M_{3jet}} \cdot \left(\sum_{i=1}^{N_{evt}} \frac{1}{\epsilon_V^i} \right) \cdot C_{unsmear}$$

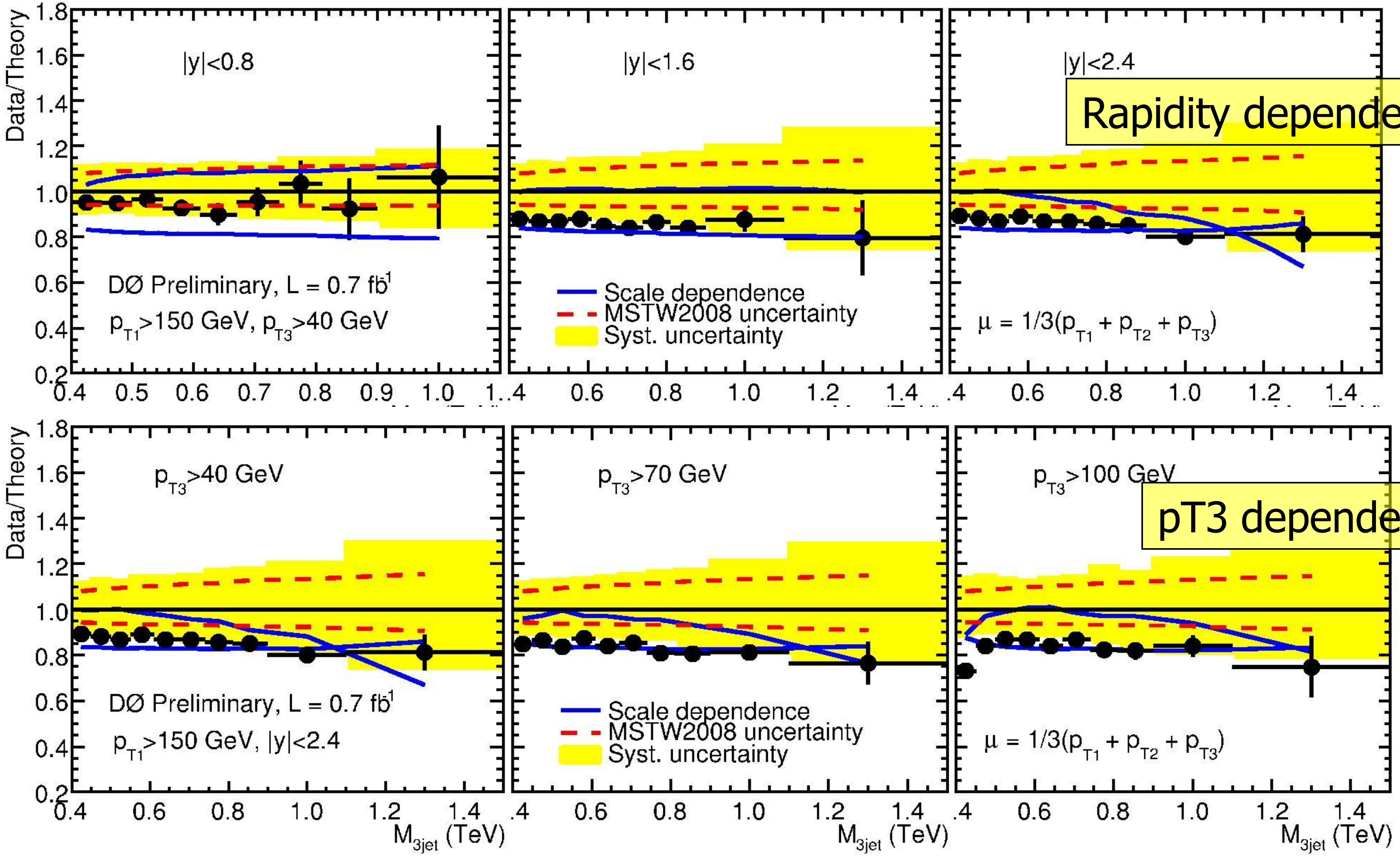
Rapidity dependence

p_T^{Jet3} dependence





Three-jet mass distrib.



Rapidity dependence

pT3 dependence

Well described by pQCD: 1st test 3-jet NLO cross section!

$R_{3/2}$: Introduction

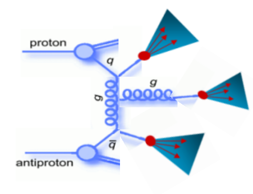
Goal: test pQCD (and α_s) independent of PDFs

Conditional probability:

$R_{3/2}$

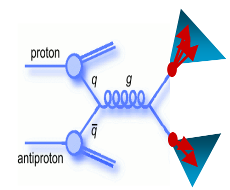
$= P(3^{rd} \text{ jet} \mid 2 \text{ jets})$

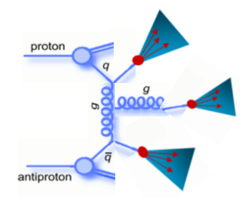
$= \sigma_{3\text{-jet}} / \sigma_{2\text{-jet}}$

$\sum$ 

$+ \ldots$

divided by

$\sum$ 

$+$ 

$+ \ldots$

- Probability to find a third jet in an inclusive dijet event
- Sensitive to α_s (3-jets: α_s^3 / 2-jets: α_s^2)
- (almost) independent of PDFs

$R_{3/2} = \sigma_{3\text{-}jet} / \sigma_{2\text{-}jet}$

Measure as function of two momentum scales:

- p_{Tmax} : common scale for both $\sigma_{2\text{-}jet}$ and $\sigma_{3\text{-}jet}$
- p_{Tmin} : scale at which 3rd jet is resolved ($\sigma_{3\text{-}jet}$ only)

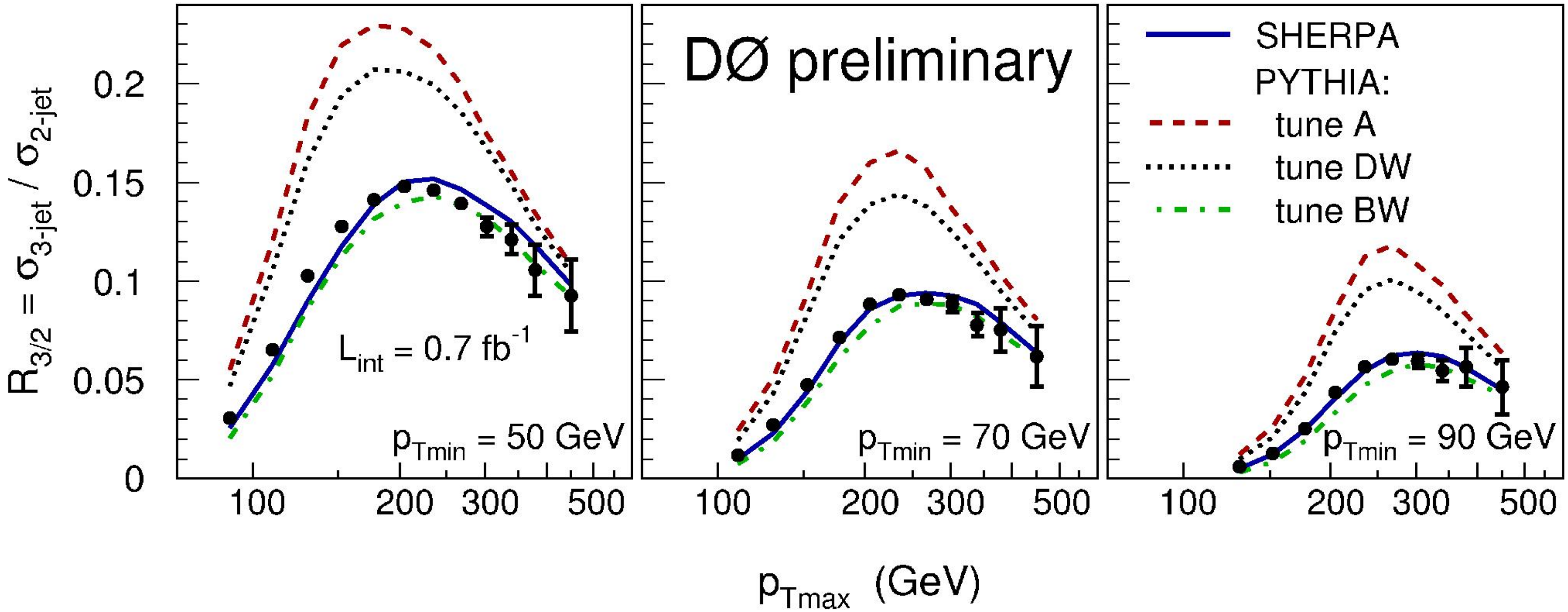
Sensitive to α_s at the scale p_{Tmax}
→ probe running of α_s in Tevatron energy regime → up to 500 GeV

Details:

- inclusive *n*-jet samples (*n*=3,2) with *n* (or more) jets above p_{Tmin}
- $|y|<2.4$ for all *n* leading p_T jets
- $\Delta R_{jet,jet} > 1.4$ (insensitive to overlapping jet cones)
- study p_{Tmax} dependence for different p_{Tmin} of 50, 70, 90 GeV

→ Measurement of $R_{3/2}(p_{Tmax}\,;\,p_{Tmin})$

$R_{3/2} = \sigma_{3\text{-}jet} / \sigma_{2\text{-}jet}$



SHERPA: good description (default version w/ MSTW2008LO PDFs)

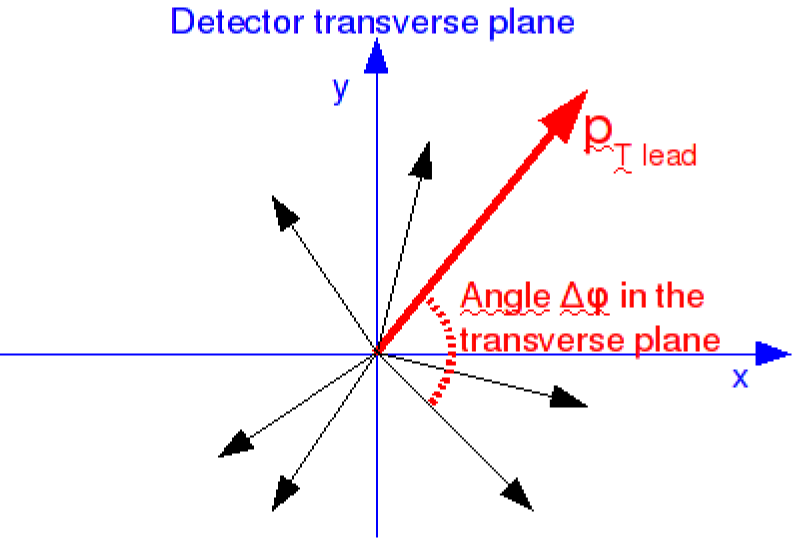
PYTHIA: huge dependence on tune

- Reasonable description by tune BW
- Popular tunes A, DW → totally off

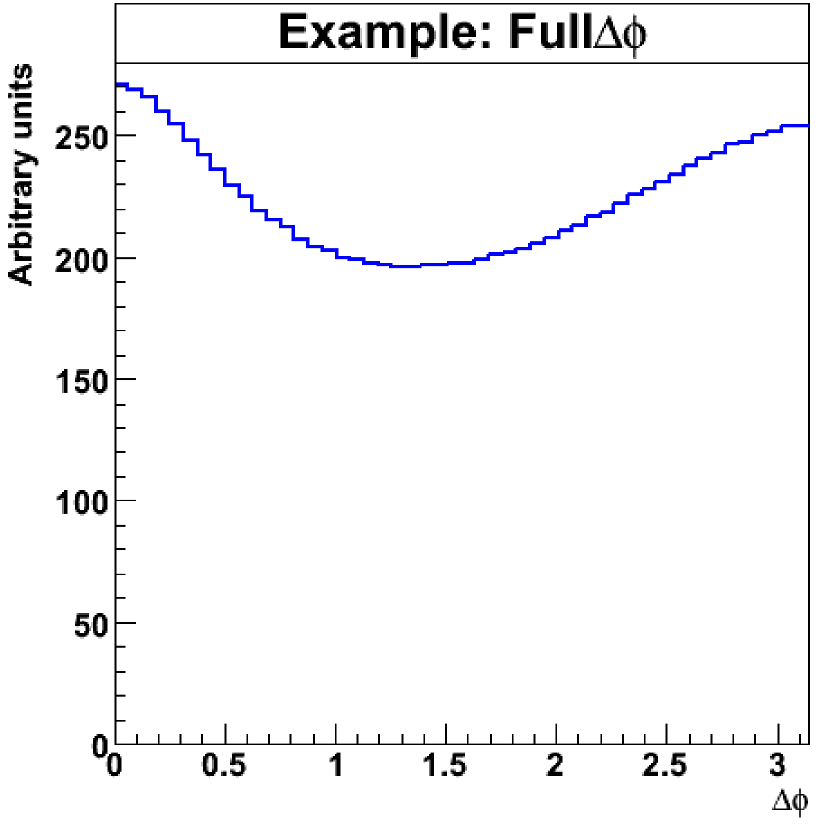
Maybe: extract strong coupling → up to p_T>400 GeV (yet untested)

Track Correlations in Minimum Bias Events

- Use correlations in Δ φ to characterize Minimum Bias Events
- Compare data to various Monte Carlo tunes and models



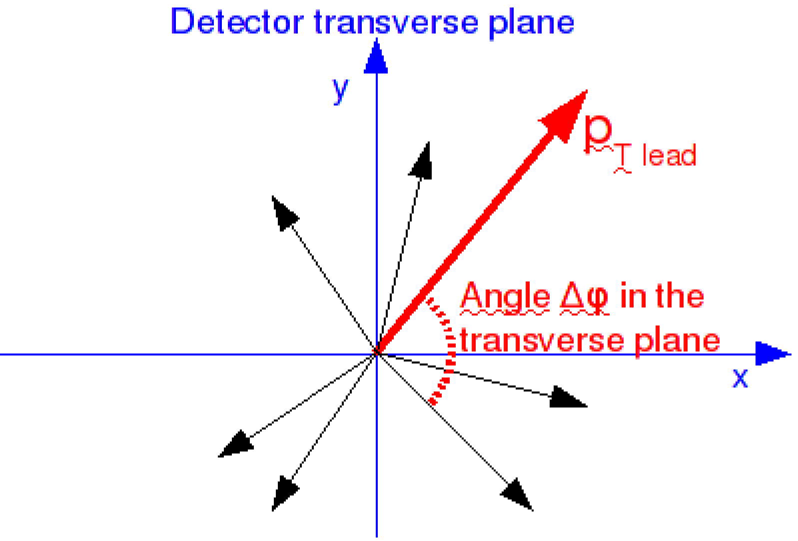
From full distribution…

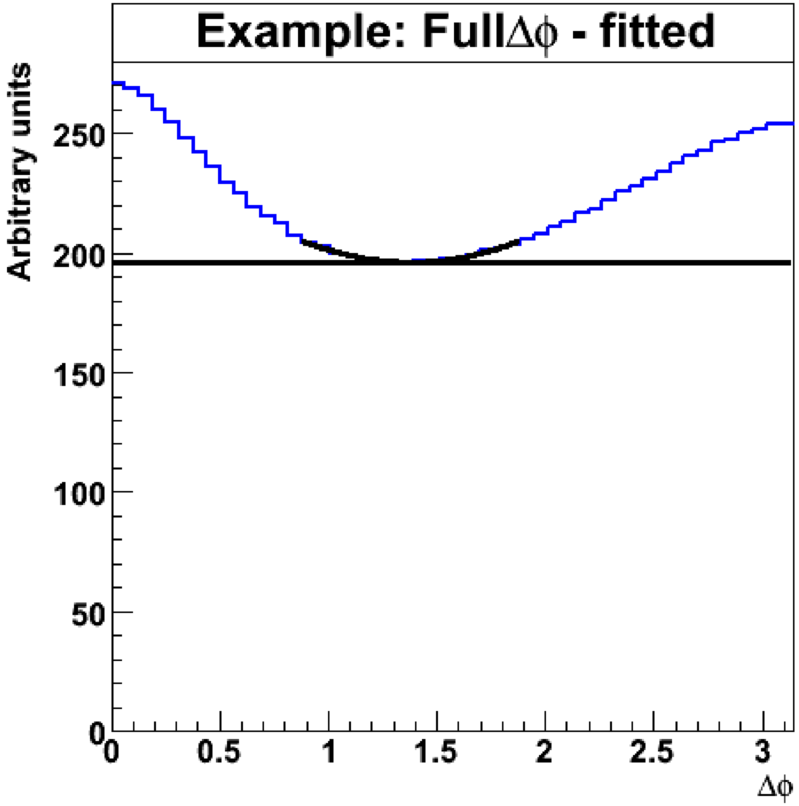


Track Correlations in Minimum Bias Events

- Use correlations in Δ φ to characterize Minimum Bias Events
- Compare data to various Monte Carlo tunes and models

Fit minimum: subtract to remove pedestal and suppress fakes, noises, …

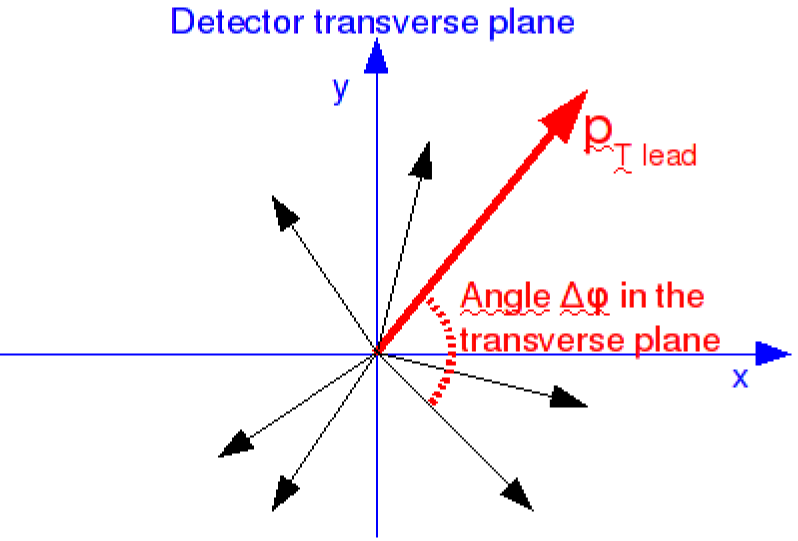


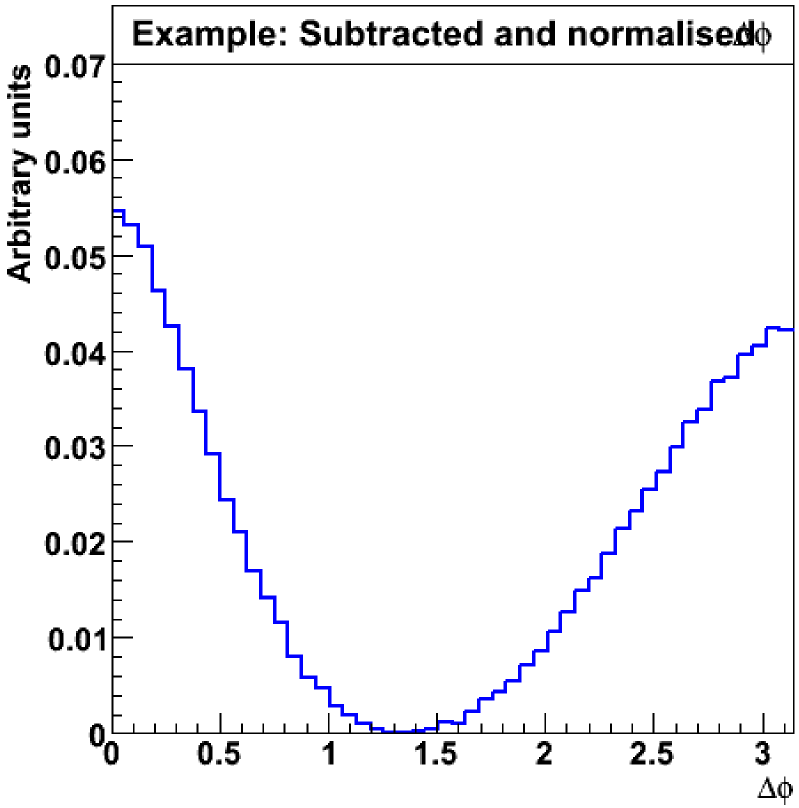


Track Correlations in Minimum Bias Events

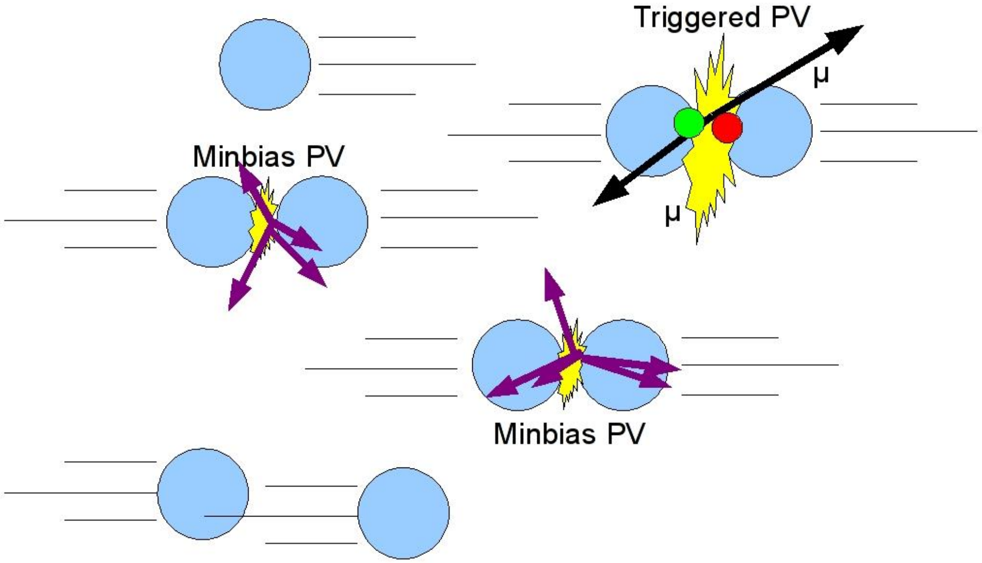
- Use correlations in $\Delta\ \varphi$ to characterize Minimum Bias Events
- Compare data to various Monte Carlo tunes and models

Subtract then normalize to get crest shape observable





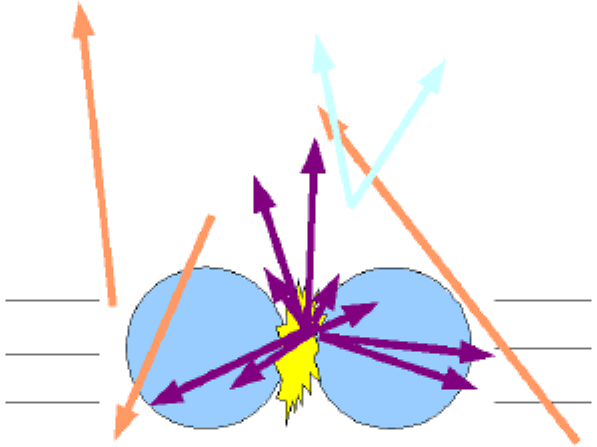
Choosing a Minimum Bias Event Sample



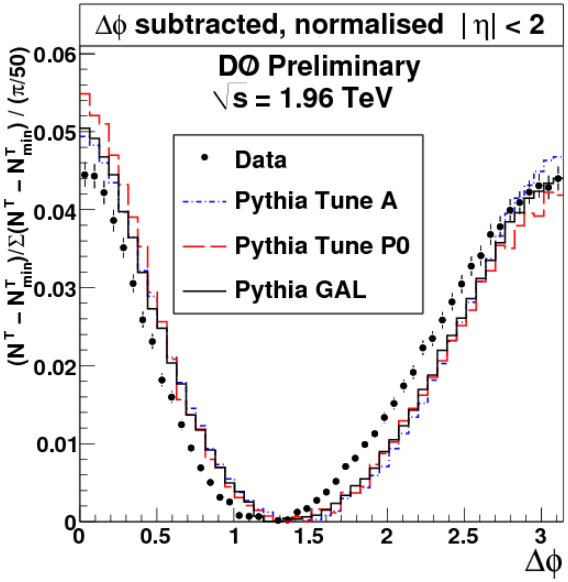
- Trigger on dimuon events
- Require exactly 2 muons w/ p_T > 2 GeV associated with the same primary vertex (PV)
- Then require one or more Minimum Bias PVs
  - At least 5 tracks
  - At least 0.5cm from triggered PV
  - Within 20cm of center of detector

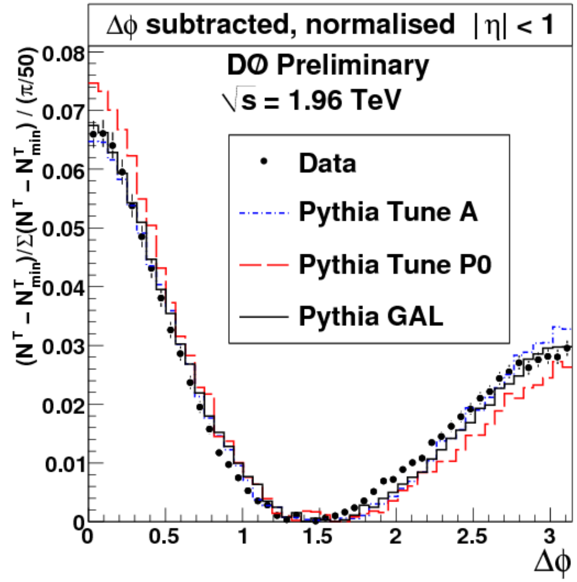
Strategy: Associate all tracks to PVs and then select good quality tracks associated to minbias PVs. Minimize fakes, cosmics, conversions, long-lived resonances, vertex mis-associations

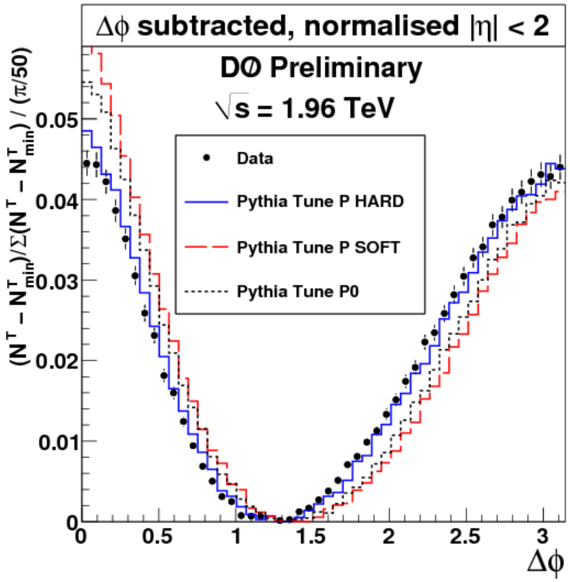
- $p_T > 0.5$GeV
- $|\eta| < 2$

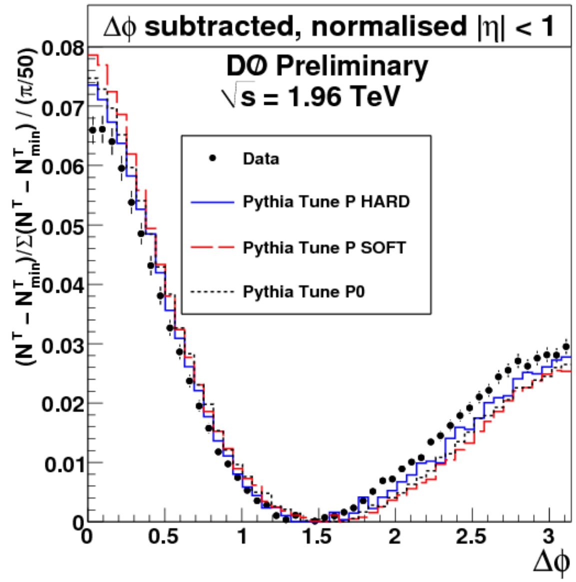


Δφ comparison to MC



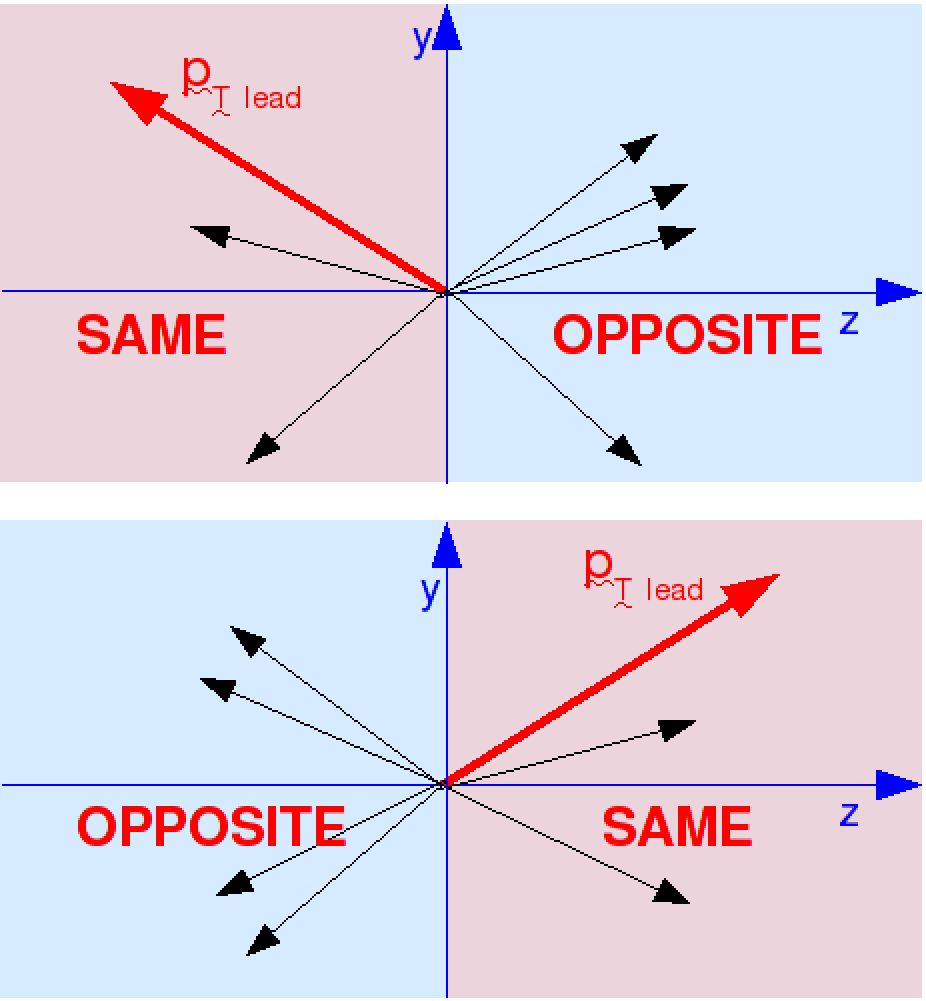






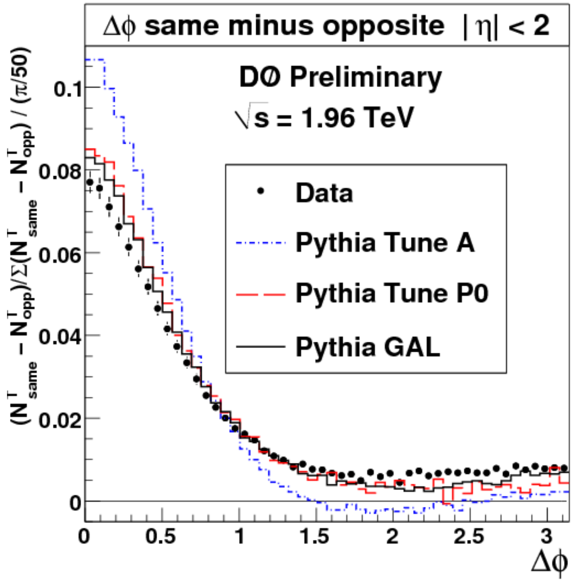
Opposite vs Same Side

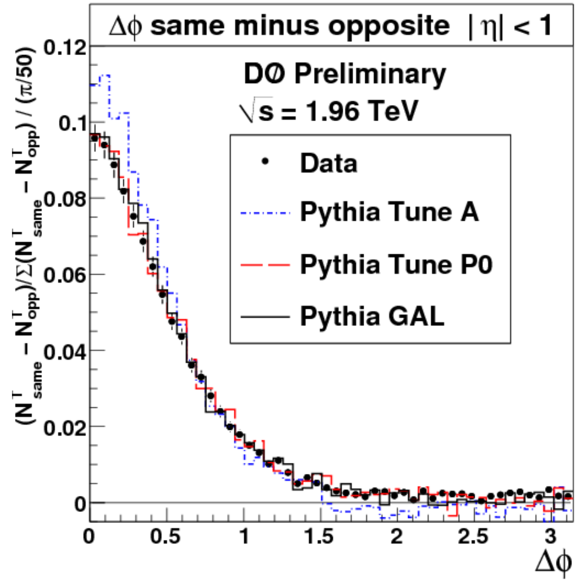
Detector beam-axis plane

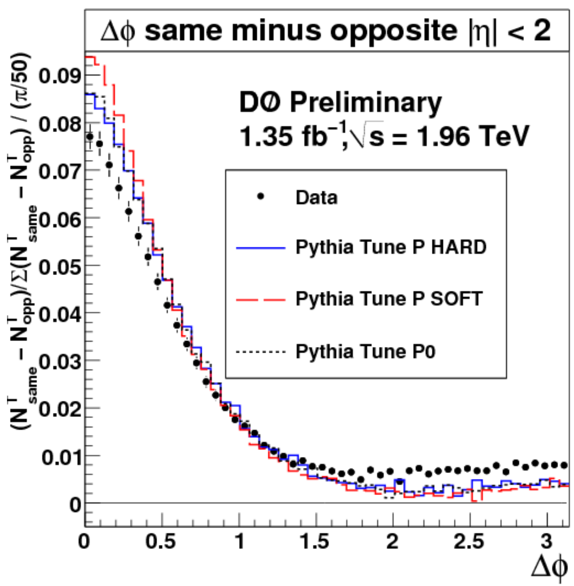


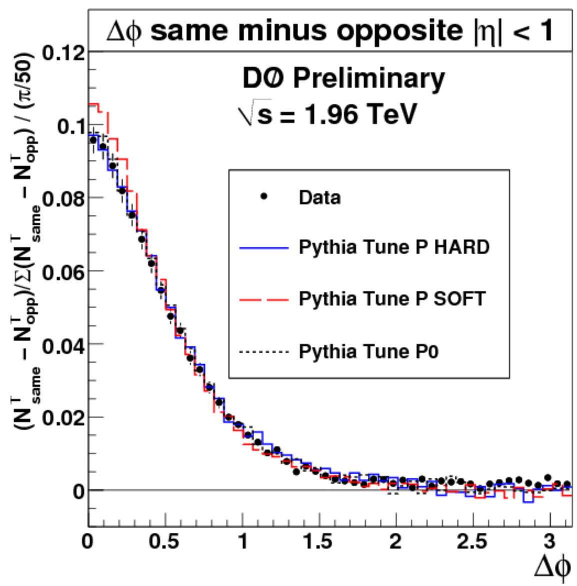
- Subtract opposite side from same side distribution
- Removes unwanted effects from uncorrelated fakes and tracking efficiencies

Δφ comparison to MC









Conclusions

D0 Three-jet Mass Results

- First measurement at the Tevatron of corrected 3-jet mass distribution
- First comparison to NLO prediction for 3-jet cross-section

D0 Multijet Ratios $R_{3/2}$ Results

- High precision test of pQCD
- Comparisons to NLO prediction underway
- Can be extended to other ratios ($R_{4/2}$, $R_{4/3}$, etc) & extraction of α_S.

Minimum Bias $\Delta\phi$ Correlation Results

New style observables give us new discriminative power between MC tunes/models.

- Deviations between data and PYTHIA models/tunes vary greatly. No tune fits both variables simultaneously.
- First analysis step in planned and ongoing further studies of minbias/UE